

# **NASA SBIR 2007 Phase I Solicitation**

### S4 Low-Cost Small Spacecraft and Technologies

The Low-Cost Small Spacecraft and Technologies Topic focuses on the technologies, subsystems, methodologies, and mission concepts for space missions which lower the over-all cost for scientific exploration. The "Small" of spacecraft and missions refer to small spacecraft that have "wet" masses below 500 Kg. (micro satellites 10-100kg, nano satellite 1-10kg, pico satellite

# **Subtopics**

# S4.01NanoSat Launch Vehicle Technologies

Lead Center: ARC

The space transportation industry is in need of low-cost, reliable, on-demand, routine space access. Both government and private entities are pursuing various launch systems and architectures aimed at addressing this market need. Significant technical risk and cost exists in new system development and operations - reducing incentive for private capital investment in this still-nascent industry. Public and private sector goals are aligned in reducing these risks and enabling the development of launch systems capable of reliably delivering payloads to low Earth orbit. The NanoSat Launch Vehicle Technology subtopic will particularly focus on higher risk entrepreneurial projects for dedicated nano and small spacecraft launch vehicles.

This subtopic is seeking proposals in the following, but not limited, areas:

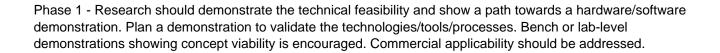
- Conceptual designs of system/architectures capable of reducing the mission costs associated with small payload delivery to LEO.
- Maturation of low-cost propulsions systems using low-cost materials, and/or low-cost manufacturing processes.

- Maturation of low-cost propulsion systems using storable and environmentally friendly non-toxic propellants.
- Innovative propulsions system solutions, including robust integrated micro-propulsion systems for both primary propulsion, as well as on-board satellite propulsion.
- Maturation of hypersonic and small launch vehicle design and analysis tools or tool-sets aimed at increasing the state-of-the-art while reducing the required design cycle time and human interaction.
- Maturation of key technologies/processes for hypersonic and small launch vehicles including, but not limited to:
  - Thermal Protection Systems;
  - Airframe and subsystem structures that increase system performance and propellant mass fraction;
  - Vehicle Sensor Networks.
- Novel, low-cost modular adapters and release mechanisms.
- · Lightweight interstage designs.

Applications of wireless networking technologies for small launch vehicles are also specifically of interest to this subtopic. This technology could be used for vehicle to ground communications (spread-spectrum and non-licensed technologies), as well as within the vehicle itself. We desire new architectures for intelligent on-board communications as well as satellite-to-satellite communication using machine-to-machine (M2M) solutions. The traditional wire harness architecture could be replaced by the wireless technology for command and control, which would reduce vehicle mass and improve reliability. Also stage-to-stage interfaces and vehicle-payload interfaces are of interest. These wireless technologies can include but are not limited to WIMAX<sup>TM</sup> and ZIGBEE<sup>TM</sup>.

Non-propulsive approaches and architectures for new launch vehicles can also achieve increases in launch vehicle payload mass delivered to orbit for small spacecraft missions. Offerors should consider development, test, and operational factors to show improvements in development and operational costs, payload mass fraction, and mission assurance. Special attention should be given to improved integration between the launch vehicle and payloads to further reduce operational costs. Furthermore, non-propulsive launch vehicle technologies have a dramatic impact on launch vehicle performance and constitute a large percentage of development and operational costs. They include, but are not limited to:

- Robust On-Board Guidance, Navigation and Control (GN&C) avionics. GN&C should be modular (including modular software architectures) and make use of modern architectures, including highperformance low-weight avionics hardware, and modern software tools. Emphasis is on low-weight architecture to allow maximum payload capacity.
- Range safety solutions and operational concepts to lower costs. These may include alternative solutions to
  expensive explosive destruct packages, including, but not limited to propulsion-cutoff systems, autonomous
  flight-abort systems, etc.



Phase 2 - Emphasis should be placed on developing and demonstrating the technology under relevant test conditions. Additionally, a path should be outlined that shows how the technology could be commercialized or further developed into space-worthy systems. When applicable, researchers should deliver a demonstration unit for functional and environmental testing at the completion of the Phase 2 contract.

### S4.02Secondary and Tertiary Launch Technologies

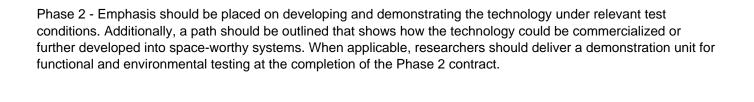
### Lead Center: ARC

There are a growing number of secondary and tertiary flight opportunities for small spacecraft. These include Dual Payload Attach Fitting (DPAF) for the Delta launch vehicle, the EELV Secondary Payload Adapter (ESPA), as well as tertiary opportunities for spacecraft that are bolted to the upper stage of a booster (as was the case with GeneSat on the Minotaur launch vehicle). The Secondary and Tertiary Launch Technologies subtopic will particularly focus on adaptor and deployment technologies.

We specifically desire low-cost modular DPAF and ESPA solutions, which can be adapted for various nano and small-satellites. Solutions should have minimal impact on cost and schedule, protect the primary payload, and have clear and achievable paths to certification. Topics include, but are not limited to:

- Gentle non-explosive separation mechanisms;
- Autonomous or on demand deployment with build in safety factors;
- Robust, low-weight, and low-cost innovative deployment architectures for large numbers of nano- and small-satellites into predefined orbits.

Phase 1 - Research should demonstrate the technical feasibility and show a path towards a hardware/software demonstration. Plan a demonstration to validate the technologies/tools/processes. Bench or lab-level demonstrations showing concept viability is encouraged. Commercial applicability should be addressed.



### S4.03Low-Cost, Rapid Spacecraft Design and Multi-Subsystem Functionality

#### Lead Center: ARC

To achieve low-cost small spacecraft missions, the resources necessary for the conceptual and detailed design of the spacecraft should be proportional to other phases of the successful project. Novel approaches are encouraged to re-use development from other projects and design current projects with the foresight to be reused for future flight projects. The Low-Cost, Rapid Spacecraft Design and Multi-Subsystem Functionality subtopic encourages offerors to utilize open source software and hardware solutions to be utilized for other actors, including entrepreneurial and university teams, for reusability.

This subtopic is seeking proposals in the following, but not limited, areas:

- Methods and tools to enable a geographically distributed, concurrent design of system concepts and functions.
- Dynamic, open source, on-line database and collection system of COTS components and subsystems suitable for spacecraft - a database of components open to the public, can be used for conceptual design and to determine an accurate Master Equipment List (MEL), cost, and schedule based on the current market value and lead time for the components; a prospective model. Such a database should include an API where companies can:
  - Plug into a design tool, whether open source or proprietary, to utilize the database for a prospective model:
  - Link to their components already publicized on their own webpage to collect the data on one centralized location;
  - Utilize database to extend options from a proprietary database of components or designs.
- Modular and scalable subsystem design of spacecraft.

- Consolidation of spacecraft functions to reduce mass, power, volume and interfaces (i.e., multi-functionality) integrating the functions of two or more onboard disciplines such as structure/mechanical, power, avionics, telecommunications, propulsion, thermal control and attitude control and determination. Also consider cross-functional spacecraft-to-payload capabilities in the areas of attitude determination, navigation, telecommunications and other mission level functions.
- Internal wireless data and command communications systems that alleviate need for wire harness.

Phase 1 - Research should demonstrate the technical feasibility and show a path towards a hardware/software demonstration. Plan a demonstration to validate the technologies/tools/processes. Bench or lab-level demonstrations showing concept viability is encouraged. Commercial applicability should be addressed.

Phase 2 - Emphasis should be placed on developing and demonstrating the technology under relevant test conditions. Additionally, a path should be outlined that shows how the technology could be commercialized or further developed into space-worthy systems. When applicable, researchers should deliver a demonstration unit for functional and environmental testing at the completion of the Phase 2 contract.

### S4.04Project Management, Systems Engineering and Mission Assurance Tools

## Lead Center: ARC

For cost effective management of multiple complex low-cost small spacecraft projects using distributed teams, management tools are required that integrate the various elements of management, systems engineering, and risk and mission assurance data. This subtopic is seeking tools where members of a spacecraft team are able exchange technical information and capture the salient decisions, trades, dependencies, etc. For a tool to be effective, it must make the job for each team member easier. There should be customizable views for each member so they are able to see the data that affects their job. This subtopic is seeking tools that:

- Simplify data integration resulting in top level roll-up or "dashboard" views as well as provide managerfriendly deep-drilling capability when depth of technical insight is required.
- Directly reflect the management and reporting requirements for NASA projects as defined in NPR7120.5D, NPR 7123.1A, NPR 8000.4, and related standards and directives.
- Facilitate or automate data entry for the Project Manager, Systems Engineer, and Risk and Mission Assurance Manager through secure web-based interfaces.
- Perform data integrity checks at the time of entry and upon request. Include automated e-mail notification
  of data integrity problems to responsible parties.

- Provide common-interface input portals and data library structures for data uploading from each project WBS element.
- Provide manager-controlled cross-linking of access to data resources from WBS to WBS.
- Provide the ability to specify and automatically generate and update metric and trend reporting on key
  performance measures, quantities and changes in requirements, documents, configuration items, risk
  databases, and cost tracking including Earned Value Management metrics and schedule critical path and
  resource loading metrics.
- Make it possible for reasonably experienced managers to train themselves on tool use.
- Provide data entry and presentation interfaces that are reliable, accepting and presenting data without lengthy uploads or downloads.
- Provide simple, user-modifiable linking to related, keyword searchable archives.
- Provide data translation and capture tools for integration of any data that can be provided in spreadsheet formats or common text documents.
- Aid in building re-usable reporting formats linked to data resources including metric analysis data, snapshots of discipline-specific report sheets, standard subsystem progress reports, and other manager specified data.
- Provide integrated management and team support tools such as Action Item tracking including automatic email alerts to individual and groups, and customizable tracking status schemes.

Data resources to be linked include cost tracking spreadsheets, task plans, risk management databases, requirements databases, technical performance metrics and margins sheets, top level and WBS element schedules, and standard monthly status reports from WBS elements. The tool should be easily scalable for large or small projects and the number of WBS elements and features included or excluded for a given project should be user-selectable. User and group permission and access controls are required.

Phase 1 - Research should provide examples of proven cost benefits and project successes based on the use of integrated management tools for management of multiple simultaneous distributed projects. Architectures should be proposed for implementation of an integrated multi-project management tool.

Phase 2 - A management tool set will be implemented and demonstrated as part of an actual small satellite management project. The tool will be evaluated for ease of use, effectiveness as a NASA project set-up tool, management information tool, and reporting tool. Feasibility for a single manager to effectively manage and report on multiple simultaneous projects will be assessed. Project users from the WBS elements of the satellite project will evaluate ease of use of uploading data.

# S4.05Smart, Autonomous Command and Data Handling System, Algorithms and Data Management

### Lead Center: ARC

The cost of flight software, including algorithms and data management, is continuing to increase and multiply in complexity. Novel on-board data analysis can greatly decrease the bandwidth needed back to Earth, and can alert scientists for time sensitive information and follow-up investigations.

This subtopic is seeking proposals in the following, but not limited, areas:

- · Innovative flight software development techniques
  - Planning and scheduling software
  - Modular routines for repeatability on future missions.
- Autonomous fault tolerant software development that acts in a repeatable, predictable manner.
- · Automated system level testing.
- On board automated approaches for data compression and payload data analysis to enable low bandwidth communications to the ground station.
- Participatory, distributed analysis techniques utilizing public interest and resources (e.g., Stardust @ Home and HiRise data analysis).

Phase 1 - Research should demonstrate the technical feasibility and show a path towards a software demonstration. Bench or lab-level demonstrations showing concept viability is encouraged. Commercial applicability and modularity should be addressed.

Phase 2 - Emphasis should be placed on developing and demonstrating the software technology under relevant test conditions. Additionally, a path should be outlined that shows how the technology could be commercialized or further developed into space-worthy systems. Researchers should deliver a demonstration package for functional evaluation by NASA at the completion of the Phase 2 contract.

### **S4.06Advanced Avionics**

Lead Center: ARC

This subtopic is seeking proposals to reduce the cost, mass, size, power and complexity of current spacecraft avionics systems, including processors, switch boxes, payload control units, mass storage devices, star trackers, IMUs, and power converters to support smaller (micro and nano) class space vehicles.

NASA has been studying methods to assemble space missions quicker and in a more straightforward manner using "plug and play" (PnP) approaches. Modern plug-and-play includes both the traditional boot-time assignment of I/O addresses and interrupts to prevent conflicts and identify drivers, as well as hot plug systems such as USB and Firewire. This SBIR will explore the hallmarks of next-generation avionics. A major challenge to achieving a usable and useful low cost small mission is the ability to rapidly compose the system to perform both the needed mission functionality using the available spacecraft components. Physical assembly of the PnP spacecraft components is a necessary, but insufficient condition for achieving a system. The assembled system needs to provide the functional capabilities to support the intended mission and also needs to provide the functional capabilities to ensure the operational health and safety of the resulting space mission. A preliminary architectural model to provide a reusable infrastructure is requested as part of effort this supports hard real time, soft real time and non-real time processes.

The objective of this SBIR effort is to prove the viability of modular, plug and play (PnP) spacecraft avionics architecture. This revolutionary architecture provides a near-term solution to modular, plug and play avionics while distributing power and data management functions. It enables full PnP modularity reducing spacecraft integration and test to a few days.

Areas of interest include:

- · Low cost open architecture avionics systems;
- Plug and Play adapters that facilitate transition from traditional point to point proprietary control to an open architecture industry standard interface both hardware and software;
- Validate components by producing low cost standard plug and play components including processors, switch boxes, payload control units, mass storage devices, star trackers, IMUs, and power converters.

Phase 1 - Research should identifying and evaluating candidate telecommunications technology applications to demonstrate the technical feasibility and show a path towards a hardware/software demonstration. Plan a

demonstration to validate the technologies/tools/processes. Bench or lab-level demonstrations showing concept viability is encouraged. Commercial applicability should be addressed.
Phase 2 - Emphasis should be placed on developing and demonstrating the technology under simulated flight conditions. Additionally, a path should be outlined that shows how the technology could be commercialized or further developed into space-worthy systems defining interfaces (both on the spacecraft and to candidate ground segments). When applicable, researchers should deliver a demonstration unit for functional and environmental testing at the completion of the Phase 2 contract.
S4.07Mini-Micro Thrusters, LOX / Hydrocarbon Propulsion, and Attitude Control Systems
Lead Center: ARC  This subtopic is seeking proposals that explore uses of technologies that will provide superior performance in attitude control and overall orbit control.
Propellants play a vital role. The use of liquid oxygen / liquid hydrocarbon fuel (e.g., liquid propylene (LP) in small spacecraft for implementing attitude control and for orbital maneuvers is of interest. This subtopic is looking for candidate fuels that have superior performance to kerosene for on-orbit applications including storage stability and propulsion.
This subtopic is also seeking proposals in the following, but not limited, areas:
<ul> <li>Low-cost reaction wheels;</li> <li>Low-mass micro-propulsion systems;</li> </ul>
<ul> <li>Propulsion systems that allow transfers from LEO or GTO to lunar orbit or other destinations;</li> </ul>
Propellantless means to achieve delta-V (e.g., momentum exchange, electrodynamic interaction with the Earth's magnetosphere) as a viable Cis-Lunar transport system;

<ul> <li>Flexible and modular (i.e., non-customized) tankage that is scalable to accommodate multiple mission delta- V requirements without safety and design re-qualification for each mission.</li> </ul>
Phase 1 - Research should demonstrate the technical feasibility and show a path towards a hardware/software demonstration. Plan a demonstration to validate the technologies/tools/processes. Bench or lab-level demonstrations showing concept viability is encouraged. Commercial applicability should be addressed.
Phase 2 - Emphasis should be placed on developing and demonstrating the technology under relevant test conditions. Additionally, a path should be outlined that shows how the technology could be commercialized or further developed into space-worthy systems. When applicable, researchers should deliver a demonstration unit for functional and environmental testing at the completion of the Phase 2 contract.
S4.08Low-cost Assembly, Integration, and Testing
Current programs take a step-wise approach to various phases of space missions that may lead to inconsistencies between conceptual development, design, assembly, integration, testing, and operations. This subtopic seeks to integrate these phases by providing a consistent software/hardware environment for spacecraft development to operations. Extensible/modular, standards-based, and COTS solutions for software and hardware to improve transition through the various phases, especially transition to operations, is highly encouraged.
One of the potential benefits of small spacecraft missions is transformation of the payload integration process. Traditionally payloads and experiments were delivered to payload integration facilities that were geographically close to the launch site.
This subtopic is looking for ways to streamline this process by reducing the need for this activity to be carried out to close proximity to the launch site. This will result in integration occurring at home facilities and reduced lead times due to a decrease in associated planning activities.
Similarly, to facilitate integration of spacecraft subsystems when using COTS products from multiple vendors,

interfacing hardware that can accommodate an array of interface standards including Ethernet, Spacewire <sup>™</sup> , USB 2.0, RS-422, and I2C.
This subtopic is seeking proposals in the following, but not limited, areas:
Automated test equipment / automated Breakout boxes;
<ul> <li>Testing of subsystems in geographically distributed locations;</li> </ul>
Standardized interfaces with launch vehicles with frequent launch opportunities.
Phase 1 - Research should demonstrate the technical feasibility of systems-level approach to streamlining processes while simultaneously improving program consistency, repeatability, improved testing, and lower cost. Additionally, the scope of Phase 1 includes identification and evaluation of these alternative subsystem integration, test, and payload processing architectures, as well as the associated payload accommodations hardware and technologies that might be required. Commercial applicability should be addressed.
Phase 2 - Emphasis should be placed on developing and demonstrating the technology under test conditions based on emerging nanosat and small launch vehicles now in development or integration with secondary and tertiary payload launch opportunities. Additionally, a path should be outlined that shows how the technology could be commercialized or further developed into space-worthy systems. When applicable, researchers should deliver a demonstration unit for testing at the completion of the Phase 2 contract.
S4.09Autonomous Multi-Mission Virtual Ground and Spacecraft Operations
Lead Center: ARC
Future ground and spacecraft operations for low-cost spacecraft missions must decrease the complexity, cost, and human intervention required for successful operations of missions.
This subtopic is seeking proposals in the following, but not limited, areas:

- · Virtual ground stations;
- Internet-based protocol modules and architectures that will provide seamless network command and control continuity between terrestrial and space-based platforms and environments;
- Autonomous lights-out ground control software (e.g., the ground station operates autonomously without human intervention, and can have remote access);
- Alternate Ground station approaches (e.g., Antenna Arrays or Amateur Radio bands);
- Networked operations of distributed ground stations (e.g., University consortium);
- Software/methods enhancing multiple-mission consolidated operations.

Phase 1 - Research should demonstrate the technical feasibility and show a path towards a hardware/software demonstration. Plan a demonstration to validate the technologies/tools/processes. Bench or lab-level demonstrations showing concept viability is encouraged. Commercial applicability should be addressed.

Phase 2 - Emphasis should be placed on developing and demonstrating the technology under relevant test conditions. Additionally, a path should be outlined that shows how the technology could be commercialized or further developed into space-worthy systems. When applicable, researchers should deliver a demonstration package for functional and environmental testing at the completion of the Phase 2 contract.